

Cosmic Ray Issues for Liquid Argon Detectors on surface:

- Burden on Data Acquisition
- Inefficiencies (obscuring good events)
- Burden on Reconstruction/Analysis
- Physics Backgrounds (generating fake events)

Beam-spill only

Argon Drift time 2 milliseconds (3 meters at 500 V/cm)

In progress

thanks to L. Mualem of U.Minn/NOvA – NOvA note with rates and references

Burden on Data Acquisition – applies to all backgrounds:

Data Acquisition is continuous wave-form recorder on each wire.
System design (5 GB/s) can record every digitization during drift-time during inter-spill time.

DAQ has 5 GB/s bandwidth.

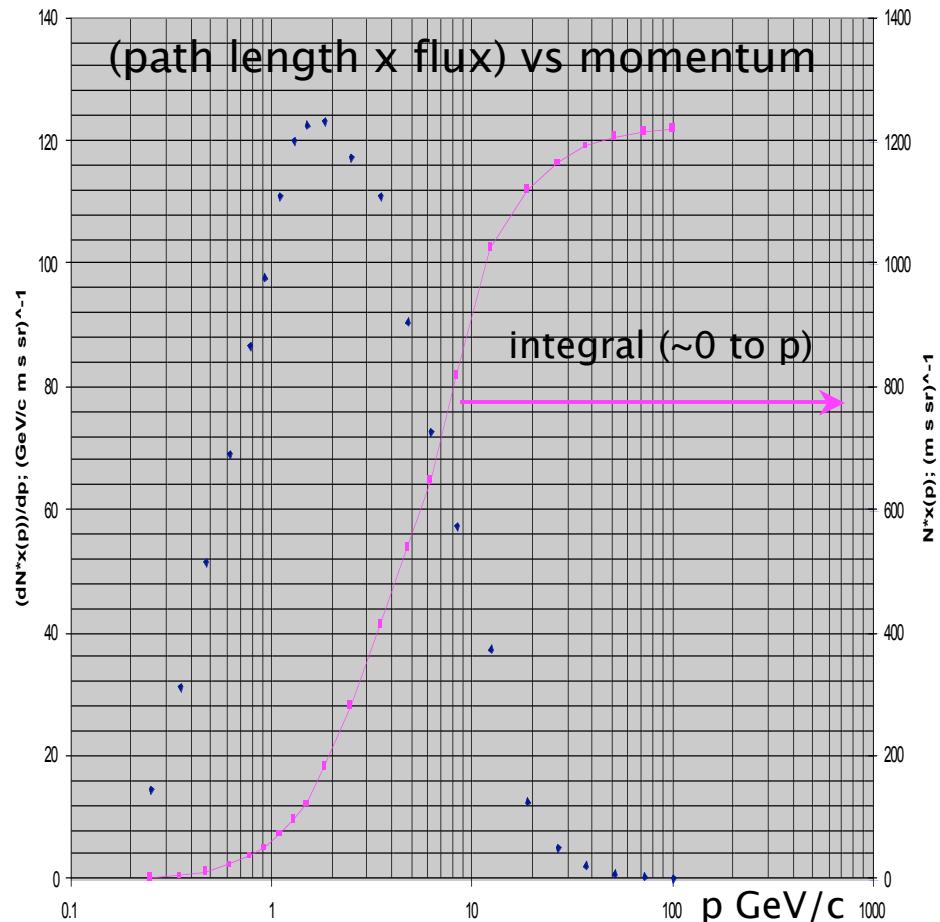
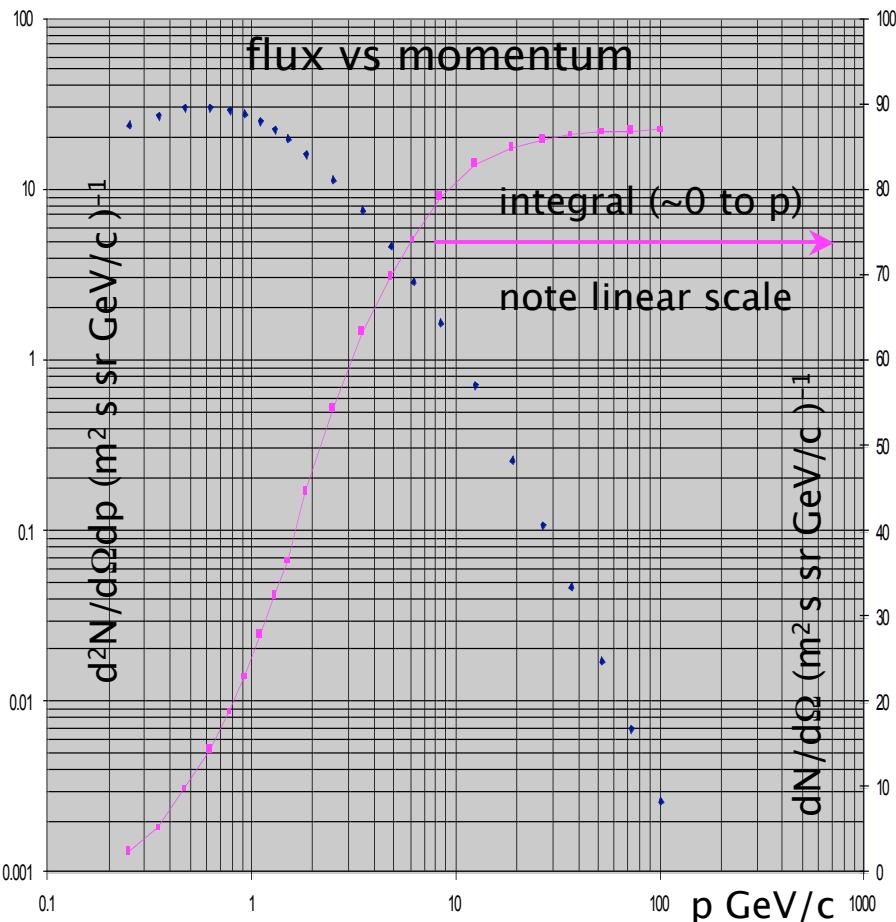
exceeds DAQ bandwidth

Run Mode -> Readout Mode	Continuous (bytes/s)	Spill Only*(bytes/s)
Every digitization	10^{12}	2×10^9 OK
Data above threshold	4×10^{10}	8×10^7 OK
Full hit processing	4×10^9 OK	8×10^6 OK

(see lartpc-docdb document 81 – flare0051.ppt)

=> Data Acquisition can cope with beam running

Cosmic Muons



Muon Rates are latitude and height dependent:

Above 1 GeV/c, $dN/d\Omega \sim 70 \cos^2(\theta)/(m^2 s sr)$; $dL/d\Omega \sim 1300 \cos^2(\theta)/(m s sr)$
 $(dE/dx \text{ in LAr is } \sim 200 \text{ MeV m}^{-1} \Rightarrow \text{typical energy is 4 GeV})$

Muons

Muon rate on 50 kton(ne) detector ~ 250 kHz (sides are 1/2 of total)

Number in sensitive time (2 milliseconds) ~ 500

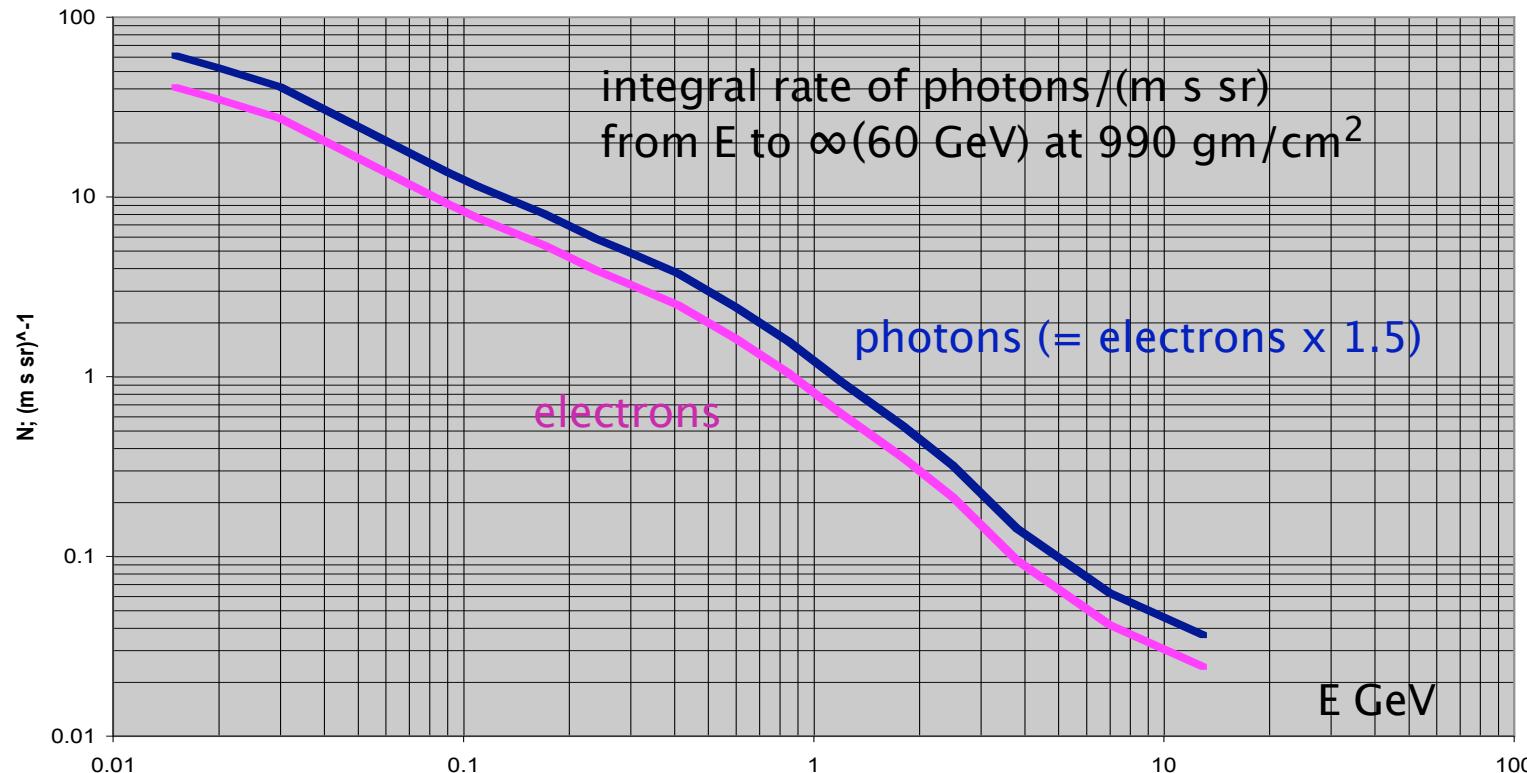
Each muon crosses 3000 wires on average..so there are 1.5×10^6 hits/spill from cosmic rays. Do these rays blind the detector?

No: even a 1 cm diameter (full signal width) tube around each ray
=> loss of 500 cm^2 out of $1000 \text{ m}^2 < 1$ part in 10^3

Rejecting/ignoring these hits *is* a major issue for the reconstruction & analysis => affects (eg) the raw data structures & the pattern recognition.

Do muon interactions (hadronic or wide-angle bremsstrahlung where the photon travels a distance from the parent muon) give background events? Follow the muon but 3×10^{20} protons => 5×10^9 muons => need rejection of $> 10^8$.

Cosmic Photons:



Rates are atmospheric depth dependent ($\Lambda \sim 160 \text{ gm/cm}^2$)

Data used here (Beuermann & Wibberenz – Can.J. Phys., 46, 1968) were taken at 760 gm/cm² and extrapolated to 990 gm/cm².

Above 1.0 GeV, $dN/d\Omega \sim 1.2/(\text{m}^2 \text{ s sr}) \sim 2\%$ of muon rate. (3 x L.M.? we need to check)

Angular distribution as $e^{-8(1/\cos(\theta) - 1)}$ (from attenuation with depth)

Photon Issues: (2% of Muon rate)

Steel and Argon outside active volume (~ 1 meter) \sim 6 attenuation lengths
= reduction of 400 => not a major burden on reconstruction/analysis.

Need (further) rejection of 10^4 for physics backgrounds.

Rejection factors available in LArTPC:

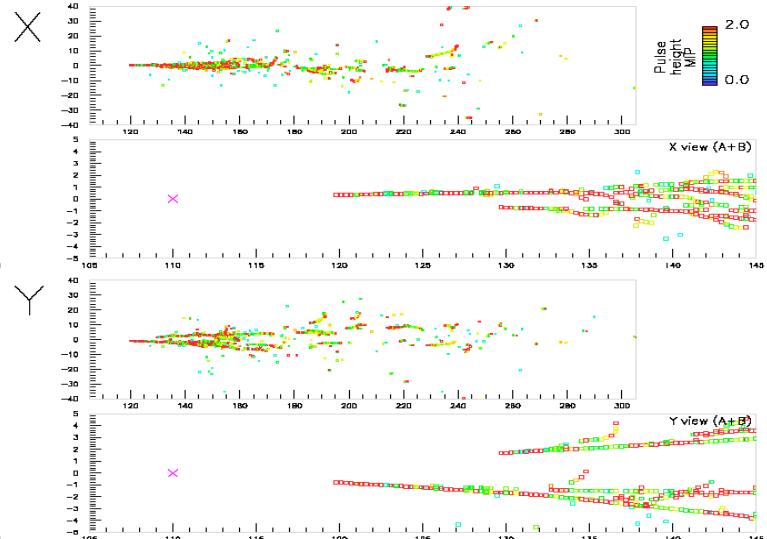
Require hadronic activity;

Require one track that starts from vertex as minimum ionizing for >2 cms
and produces a shower;

Require event pointing back to Fermilab;

Study starting

photons from π^0 s – note clean vertices



ν_e NC interaction – note activity at vertex

